Topic E – Enviro Chemsitry Part 2 – Acid Deposition

IB Chemistry

Topic E – Enviro

Hodder Ed - Talbot

E2 Acid deposition - 1.5 hours

- E.2.1 State what is meant by the term acid deposition and outline its origins. (1)
- E.2.2 Discuss the environmental effects of acid deposition and possible methods to counteract them. (3)

E2.1 – What is Acid Deposition

- E.2.1 State what is meant by the term acid deposition and outline its origins. (1)
- **Acid Deposition** refers to the process by which acidic particles leave the atmosphere. The most well known example is **acid rain**
  - but acidic substances may also be removed by snow and fog, as well as by dry processes involving gases and solid particles.
  - Production of SO_2 (as discussed in Part 01) aids in this process

E2.1 – Carbonic Acid

- Natural rain water is **acidic**, with a pH around **5.6**
- The acidity of rain is a result of **CO_2** naturally present in the atmosphere
- When CO_2 is dissolved in water it's referred to as **carbonic acid (H_2CO_3)** but only a very small amount actually exists as a solution
  - $H_2O + CO_2 \rightarrow H_2CO_3$
- Carbonic acid molecules immediately dissociate in water to form **hydrogencarbonate ions, HCO_3^-**, and **hydronium ions, H_3O^+**
  - $H_2CO_3 + H_2O \rightarrow HCO_3^- + H_3O^+$

E2.1 – Wet Deposition

- The most important sources of acid rain are the sulfur oxides produced in power stations
- When sulfur oxides dissolve and react in rain water, solutions of sulfuric acids are formed (as discussed in E.1)
  - $SO_2 + H_2O \rightarrow H_2SO_3$
  - $SO_3 + H_2O \rightarrow H_2SO_4$
  - Another route to sulfuric acid is a gas-phase reaction of a sulfur dioxide molecule with a hydroxyl radical, OH•, to give sulfuric acid
    - $SO_2 + OH\bullet \rightarrow HSO_3\bullet + \bullet OH \rightarrow H_2SO_4$

E2.1 – Wet Deposition

- Nitrogen Oxides also contribute to acid rain. Formed in vehicle engines:
  - $HO\bullet + NO\bullet + M \rightarrow HNO_2 + M$
  - M represents the 'third body' which is an inert molecule which absorbs some of the excess energy of the reaction (in the atmosphere M is generally N_2).
- NO_2 is formed by the oxidation of NO in the atmosphere and reacts with HO•
  - $HO\bullet + \bullet NO_2 + M \rightarrow HNO_3 + M$

E2.1 – Wet Deposition

- These acids may be deposited in places other than water, such as snow and fog.
- Fog is a particular problem for high-altitude forests
- The lower temperature at high altitudes causes water vapor to condense out of the atmosphere, forming a moist 'blanket' of acidic fog which surrounds trees.

E2.1 – Dry Deposition

- **Dry deposition** refers to acidic substances such as gases and particulates leaving the atmosphere in the absence of precipitation (without rain or fog)
- Heavy particulate particles may settle out of the atmosphere under gravity.
- Acidic gases such as sulfur dioxide may have directly harmful effects on the environment without first being dissolved in rain water.

E2.2 – Environmental Effects

- E.2.2 Discuss the environmental effects of acid deposition and possible methods to counteract them. (3)
- Acid deposition effects the environment in 5 ways
  1. It affects the pH of lakes/rivers, which impacts organisms living there
  2. It affects the availability of metal ions in soil, which goes on to affect nearby plant life and surface water
  3. It directly affects plants
  4. It affects buildings and other materials
  5. It directly affects human health

E2.2 – Impact(1): Lakes/Rivers

- Below a pH of 5.5
  - Some species of fish (salmon) are killed
  - Algae, zooplankton, which are food for larger organisms
  - Prevents hatching of fish eggs
- Fish are also killed when aluminum, leached from the soil by acid rain, enters lakes and rivers.
- The function of fish gills is affected by Al, leaving the fish unable to extract oxygen from the water

E2.2 – Impact(2): Soil

- The pH of soil is a key factor which species of plants will grow
- Aluminum (naturally present in soil) forms insoluble hydroxide ($Al(OH_3)$) at high pH values.
- When pH falls due to acid rain, Al becomes soluble and is released into soil.
- Other ions (Mg, Ca, etc) which are essential for plant growth are washed away in the same fashion.
  - $2Al(OH)_3 + 2H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

E2.2 – Impact(3): Plants

- Beyond damaging soil, and lowering available nutrients, acid rain can also damage plants directly
- Acid deposition can damage leaf chlorophyll, turning leaves brown and reducing the photosynthetic ability of the plant

E2.2 – Impact(4): Buildings

- Limestone and marble are forms of $CaCO_3$ which can be eroded by acid rain:
  - $CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$
- Metallic structures (mainly steel, Fe, Al) are readily attacked. The sulfur dioxide gas may attack directly as follows:
  - $Fe + SO_2 + O_2 \rightarrow FeSO_4$
- Sulfuric acid may attack Fe as well:
  - $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$
  - $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$

E2.2 – Counteract Acid Dep.

- Limit (lower) the amount of acidic substances released to the atmosphere
  - NO_x are removed from vehicle emissions with a catalytic converter
  - SO_2 emissions from coal power plants can be decreased in several ways (scrubbers, etc)
- Addition of compounds that will aid in neutralizing acidic effects
  - Addition of limestone ($CaCO_3$)
  - Addition of calcium hydroxide ($Ca(OH)_2$)